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Establishment, Survival, and Fecundity in *Echinostoma caproni* (Trematoda) Infections in Hamsters and Jirds

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ABSTRACT: The population regulation (establishment, survival, and fecundity) was studied in *Echinostoma caproni* infections in hamsters and jirds. The *E. caproni*/hamster model had a high level of compatibility, using the criterion of initial worm establishment. The *E. caproni*/hamster model, using infections within the range of 6–50 metacercariae per hamster, was also characterized by metacercarial infectivity that was infection–dose independent, a limited capacity to expel primary infections and to mount a regulatory response to superimposed challenge worm establishment, and a reproductive potential that was negatively infection–dose dependent, using the criterion of number of eggs in the uterus of the worm. In contrast, the *E. caproni*/jird model exhibited a low level of compatibility, with a generally low and variable primary worm establishment, a limited capacity to expel primary infections, and a marked capacity to mount an effective regulatory response to both superimposed and secondary challenge infections.

KEY WORDS: Trematoda, *Echinostoma caproni*, hamster, jird, population regulation, establishment, survival, fecundity, primary infection, challenge infection, host-specific components, reproductive success.

Reproductive rate is a central issue in describing the population dynamics of parasites. Any realistic approach to analyzing this rate for helminth species with a broad spectrum of definitive hosts must take into account the host-specific component of reproductive success (Whitfield et al., 1986). The reproductive capability in the helminth–definitive host relationship is governed in part by the natural and acquired regulatory responses of the host to the parasite infection. These responses are commonly host specific and may influence essential parameters like initial worm establishment, survival, and fecundity.

The mouse possesses the capacity to mount a marked acquired regulatory response to primary and challenge *Echinostoma caproni* Richard, 1964 infection (Christensen et al., 1988; Odaibo et al., 1988, 1989). In contrast, findings by Franco et al. (1986) and Mabus et al. (1988) indicate that the ability of the hamster (*Mesocricetus auratus*) to mount an effective regulatory response to *Echinostoma* infection is quite limited. Preliminary observations in our laboratory have shown that the jird (*Meriones unguiculatus*) has low susceptibility to infection with *E. caproni*. Taken together, these findings indicate that the *E. caproni*/rodent (mouse, hamster, jird) system might be useful as a model for elucidating definitive host-specific components of the reproductive capacity of intestinal helminths.

Our study supplements available information on the regulatory response to *E. caproni* infection in NMRI mice (Odaibo et al., 1988, 1989) and provides quantitative information concerning the regulatory response in hamsters and jirds to *E. caproni* infection. The species terminology used is that introduced by Kanev (1985) (see also Christensen et al., 1988).

Materials and Methods

Four-mo-old outbred female hamsters (State Serum Institute, Copenhagen, Denmark) weighing 80-100 g and 4–6-mo-old jirds weighing 60–80 g were used in this study. Metacercariae of *E. caproni* (Egyptian strain) were obtained from *Biomphalaria glabrata* as described by Christensen et al. (1980). Rodents were infected with metacercariae via a stomach tube. Recovery of worms was conducted according to the procedure described by Christensen et al. (1986). To determine worm localization in hamster experiments, the small intestine was divided into 5 equal sections, starting from the pylorus. The number of eggs in the uterus of 10 worms from each group at each observation point was determined by dissection. The time pattern of worm expulsion was determined by recovery of worms or by weekly examination of feces for eggs, using the direct smear technique.

The statistical tests used for analyzing worm survival and challenge worm establishment were the Wilcoxon rank sum test and the Kruskall–Wallis analysis of variance of ranks. Student's *t*-test and an analysis of variance were used to analyze difference in means of uterine egg counts. This study was divided into two series of experiments.

Series 1 comprised experiments on the pattern of expulsion of primary nonchallenged infections. Groups of hamsters were inoculated with 6, 25, or 50 metacercariae per hamster, and a group of jirds was inoculated with 25 metacercariae per animal. At regular intervals following hamster infections, number of worms, uterine egg counts, and worm localization were recorded. In jird experiments, only worm numbers were recorded. Three to 6 animals were used at each recording. Series 2 comprised a study on resistance to

challenge infection in hamsters and jirds. Hamsters harboring 3-, 5-, and 12-wk-old primary infections with 6, 20, or 25 metacercariae per hamster and previously noninfected hamsters were given a challenge infection. Necropsy took place day 8 postchallenge. Jirds harboring 3-wk-old infections with 25 metacercariae per animal, jirds having expelled primary 8-wk-old infections with 6 metacercariae 2–3 wk earlier, and previously noninfected jirds were also given a challenge infection. Necropsy took place day 10 postchallenge. Within each experiment, the challenge control group was necropsied the same day as the challenged group(s). In animals given a challenge infection, worms from the primary and challenge infections were distinguished based on worm size. The percentage resistance was calculated using the following formula:

$$100 - \left(\frac{\text{mean number of worms of the challenge infection}}{\text{mean number of worms of the control group}} \times 100 \right).$$

Results

Initial worm establishment in hamsters, expressed as mean percentage worm recovery for up to week 2 postinfection, was infection–dose independent ($P > 0.05$) in infections with 6 and 25 metacercariae per hamster (63.2 and 71.2%, respectively). The variance/mean ratio of 1.3 and 2.0, respectively, in infections with 6 and 25 metacercariae per hamster revealed an only limited heterogeneity in response to primary *E. caproni* infection in the hamster. The mean percentage worm recovery of 64% at week 4 following infection with 50 metacercariae per hamster was comparable ($P > 0.05$) with the initial worm establishment in infections with 6 and 25 metacercariae per hamster. Thus, primary *E. caproni* percentage worm establishment in hamsters is infection–dose independent in the infection range of 6–50 metacercariae per hamster (Fig. 1).

The mean percentage worm recovery in infections with 6 and 25 metacercariae per hamster remained stable ($P > 0.05$) throughout the 11–13 wk observation period (Fig. 1). In infections with 50 metacercariae per hamster, worm recovery remained at the stable mean level of 30–35 worms per hamster for up to week 9. The apparent reduction in worm recovery week 11 was not statistically significant (Fig. 1). Thus, the ability of the hamster to expel primary infections with *E. caproni* for up to 13 weeks postinfection was very limited.

Number of eggs in the uterus of worms was negatively infection–dose dependent (Fig. 1). From week 4 postinfection and onwards, uterine

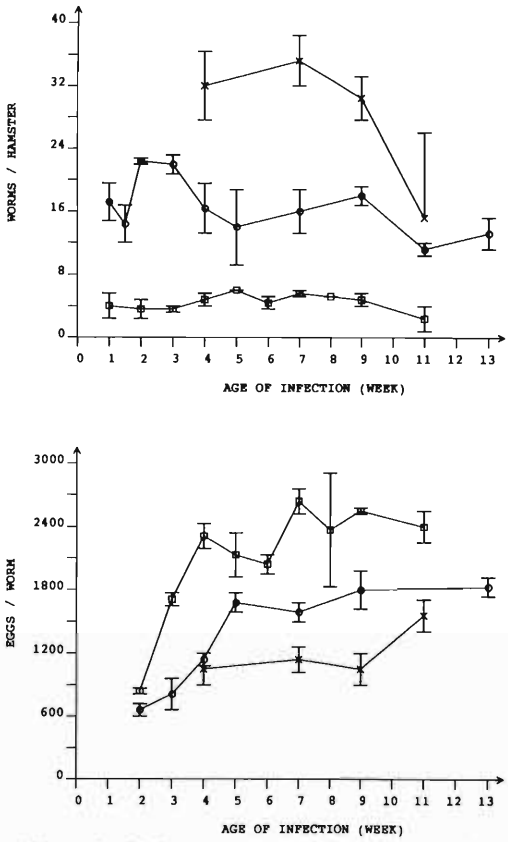

Figure 1. ***Echinostoma caproni*** **worm recovery ($\bar{x} \pm$ SE) and number of eggs in uterus ($\bar{x} \pm$ SE) at increasing age (weeks) in infections with 6 (□), 25 (○), and 50 (×) metacercariae in hamsters.**

egg counts per worm from infections with 6 metacercariae per hamster exceeded those from infections with 25 and 50 metacercariae per hamster, and uterine egg counts in infections with 25 metacercariae per hamster generally exceeded those from infections with 50 metacercariae per hamster from week 5 following infection and onwards (Fig. 1). At most observations, the differences remained statistically significant. Thus, using the criterion of uterine egg counts, the reproductive capacity per worm was negatively infection–dose dependent.

In infections with 6 metacercariae per hamster, worms were recovered only from sections 4 and 5, i.e., in the last ⅖ of the small intestine. In infections with 25 metacercariae per hamster, worms were occasionally found in section 3, especially from week 4 postinfection and onwards. In infections with 50 metacercariae per hamster, however, worms were constantly recovered from

Table 1. Resistance to secondary and superimposed *Echinostoma caproni* infections in jirds and hamsters.

Experiment no.	Experimental host	No. of animals	Age of primary infection at challenge (wk)	No. of metacercariae administered (primary/challenge)	*E. caproni* recovery ($\bar{x}$ ± SD, range)		% resistance when significant ($P < 0.05$)
					Primary	Challenge	
1	jird	5	3	25/10	8.8 ± 5.5 (3–15)	0.6 ± 1.3 (0–3)	87.2
		6	—	—/10	—	4.7 ± 2.3 (0–6)	
2	jird	5	8	6/25	expelled 2–3 wk prior to challenge	0	100
		8	—	—/25	—	5.8 ± 6.0 (0–17)	
3	hamster	4	5	20/10	10.0 ± 1.8 (8–12)	5.0 ± 1.4 (3–6)	
		3	3	20/10	12.0 ± 5.6 (6–15)	5.3 ± 3.2 (3–9)	
		3	—	—/10	—	6.0 ± 1.7 (4–7)	
4	hamster	6	12	6/25	3.8 ± 1.5 (1–5)	18.2 ± 5.1 (13–25)	
		7	12	25/25	11.4 ± 2.2 (8–14)	11.9 ± 5.1 (5–21)	41.4
		8	—	—/25	—	20.3 ± 6.2 (9–25)	

all sections except section 1. Increasing worm burdens thus result in involvement of the more anterior parts of the small intestine.

The jird exhibited a variable and overall low susceptibility to primary *E. caproni* infection. Thus, the worm establishment ($\bar{x}$ ± SD) week 1 following infection with 25 metacercariae was 5.8 ± 6.0 (23.2%; range, 0–17 worms/jird; variance/mean ratio = 6.2). Worm establishment at week 2 and week 8 was 7.6 ± 7.1 and 5.3 ± 5.7, respectively. Although the variance/mean ratio remained high throughout the 8-wk period of observation, the mean percentage worm recovery remained stable ($P > 0.05$). Thus, if allowed to become established, worms from infections with 25 metacercariae per jird persisted for a period of at least 8 wk. However, low level infections in jirds with 6 metacercariae per jird may be expelled 5–6 wk following infection (Table 1; Experiment 2, Series 2).

Results from studies on resistance to challenge *E. caproni* infection are presented in Table 1. There was marked resistance (87.2%) to superimposed infection at challenge of jirds harboring 3-wk-old infections with 3–15 worms per animal ($\bar{x}$ = 8.8). Complete (100%) resistance to secondary infection was observed at challenge 2–3 wk following expulsion of a primary infection with 6 metacercariae given 8 wk earlier (Table 1). In the hamster, the challenge worm and challenge control worm recovery remained comparable at challenge weeks 3 and 5 following establishment of primary infections with 8–12 or 6–15 worms/hamster ($\bar{x}$ = 10 and 12, respectively) and also at challenge week 12 for hamsters harboring primary infections with 1–5 worms ($\bar{x}$ = 3.8) (Table 1). At challenge week 12 for hamsters harboring primary infections of 8–14 worms per hamster ($\bar{x}$ = 11.4), there was a significant ($P < 0.05$) reduction in challenge worm recovery of 41.4%.

Discussion

Increased attention has recently been paid to the *Echinostoma*/hamster model in studies on the intestinal trematode/definitive host relationship. Fried et al. (1988) reported on the reproductive behavior in single- and 5-worm infections of *E. trivolvis*. Aspects of the infectivity, growth, and development of *E. trivolvis* were described by Franco et al. (1986, 1988), and Huffman et al. (1988) reported on some aspects of the heterologous interactions arising in concurrent infections with *E. trivolvis* and *E. caproni* in the hamster. Clinical and pathological effects and humoral and cellular responses in infections with *E. trivolvis* in the hamster were reported by Huffman et al. (1986) and Mabus et al. (1988), respectively. The present study extends earlier findings by providing information on the regulatory response of the hamster and the jird to primary and challenge *E. caproni* infections. Available information concerning the regulatory response of the mouse to *Echinostoma* infections has recently been reviewed by Christensen et al. (1988).

The results from the present study show a high level of compatibility in the *E. caproni*/hamster model, using the criterion of initial worm establishment. The *E. caproni*/hamster model is also

characterized by a primary worm establishment percentage that is infection–dose independent, a limited capability to expel primary infections and to mount a regulatory response to superimposed challenge infections, and a reproductive potential that is negatively infection–dose dependent, as judged using the criterion of uterine egg counts. Overall, the general findings from the present study on the *E. caproni*/hamster model agree with those from previous studies on the *E. trivolvis*/hamster model (Franco et al., 1986, 1988; Huffman et al., 1988; Mabus et al., 1988). In contrast to the *E. caproni*/hamster model, the *E. caproni*/jird model exhibited a low level of compatibility with a variable and overall low primary worm establishment, but with a marked capacity to mount an effective regulatory response to both superimposed and secondary challenge infections. A comparison of the regulatory response of the hamster and jird to *E. caproni* infection with that of mice (data from Christensen et al., 1988; Odaibo et al., 1988, 1989) reveals some interesting differences. Thus, the mouse and hamster may, in contrast to the jird, be categorized as highly susceptible to primary *E. caproni* establishment, and species-specific differences in expulsion capacity and in challenge worm establishment also exist. The differential response of the mouse, jird, and hamster to infection with *E. caproni* makes the *E. caproni*/rodent system highly suitable as a model for elucidating quantitative aspects of definitive host-specific components of the reproductive success of intestinal trematodes.

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